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INCLUSIVE *W* AND *Z* CROSS SECTION MEASUREMENTS AT THE FERMILAB TEVATRON

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We present recent measurements of the inclusive cross section of W and Z bosons from Run II of the Fermilab Tevatron collider.

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1. Introduction

Run II of the Fermilab Tevatron presents us with a unique opportunity to study W and Z boson physics. Compared to the LEP and SLD accelerators, where many of best measurements of electroweak parameters have been made to date, the Fermilab Tevatron has three unique advantages:

- The Tevatron produces a large flux of W bosons.
- The Tevatron is able to produce Z/γ^* bosons at high masses.
- As the colliding particles are protons and anti-protons, the W and Z bosons produced are particularly sensitive to up and down quarks.

These unique features, along with new detectors in the forward regions of the experiments, allow CDF and DØ to probe a wide range of electroweak physics.

The first electroweak physics results from the Tevatron are the inclusive W and Z cross sections. Both the CDF and DØ experiments have made measurements of the cross section times branching ratio for W and Z bosons into leptonic final states. As an example, the cross section times branching ratio for Z decaying into muons may be calculated as:

$$\sigma \cdot \mathrm{BR}(p\overline{p} \to Z \to \mu^+\mu^-) = \frac{N_{cands} - N_{backg}}{A \cdot \epsilon \cdot L}. \tag{1}$$

where N_{cands} is the number of $Z \to \mu^+\mu^-$ candidate events; N_{backg} is the estimated number of background events; $A \cdot \epsilon$ is the acceptance times efficiency for finding $Z \to \mu^+\mu^-$ candidate events and L is the integrated luminosity of the sample. The integrated luminosity is measured separately by both the CDF and DØ experiments

Table 1. Integrated luminosity, number of candidate events, background estimates and acceptance times efficiency for used for the CDF and DØ measurements of $p\overline{p} \to W \to \ell\nu$.

Signal		L	N_{signal}	background	$A \cdot \epsilon$
CDF central:	$W \to e\nu$	72 pb^{-1}	37584	$(4.4 \pm 0.8)\%$	$(18.0 \pm 0.4)\%$
CDF forward:	$W \to e\nu$	64 pb^{-1}	10461	$(8.7 \pm 0.6)\%$	$(5.2 \pm 0.2)\%$
DØ:	$W \to e\nu$	194 pb^{-1}	57109	$(7.3 \pm 0.5)\%$	$(9.6 \pm 0.2)\%$
CDF:	$W \to \mu\nu$	177 pb^{-1}	175572	$(33.6 \pm 0.4)\%$	$(22.6 \pm 0.5)\%$

Table 2. Integrated luminosity, number of candidate events, background estimates and acceptance times efficiency for used for the CDF and DØ measurements of $p\overline{p} \to Z \to \ell^+\ell^-$.

Signal			L	N_{signal}	$A \cdot \epsilon$
CDF:	$Z \to e^+e^-$	$66 < m_{ee}/\mathrm{GeVc}^{-2} < 116$	72 pb^{-1}	4242	$(22.7 \pm 0.5)\%$
DØ:	$Z \to e^+e^-$	$70 < m_{ee}/\mathrm{GeVc}^{-2} < 110$	177 pb^{-1}	4712	$(9.6 \pm 0.4)\%$
CDF:	$Z \to \mu^+\mu^-$	$66 < m_{\mu\mu}/\mathrm{GeVc}^{-2} < 116$	194 pb^{-1}	3568	$(7.3 \pm 0.2)\%$
DØ:	$Z \to \mu^+\mu^-$	$m_{\mu\mu} > 40$ GeV/c^2	148 pb^{-1}	14353	22.1% to 31.6%

with an uncertainty of $\pm 6\%$. For the W and Z signals, backgrounds come from QCD processes where a jet may fake a lepton signal, other electroweak processes and cosmic rays (for muon final states). The acceptance (A) is calculated from Monte Carlo samples; all of the other efficiencies (ϵ) are calculated directly from the data.

2. Inclusive *W* Signals

The signature of W boson decay into a charged lepton and a neutrino is a reconstructed electron or muon and a large missing-E_T signal ($\not\!\!E_T$). Missing-E_T is a measure of the imbalance of the calorimeter energy transverse to the beam direction. We calculate the 'transverse mass' of the lepton-neutrino system using only the transverse components of the lepton and neutrino momenta:

$$m_T = \sqrt{E_T(\nu) \cdot E_T(\ell) - p_x(\nu) \cdot p_x(\ell) - p_y(\nu) \cdot p_y(\ell)}. \quad (2)$$

The neutrino momentum components are taken from the $\not\!\!E_T$ calculation. Figure 1 shows the reconstructed transverse mass of muons and neutrinos from CDF. Table 1 gives the number of signal events, background, luminosity and acceptance times efficiency for the $W \to \ell\nu$ measurements. The results for the cross sections times branching ratio for $p\overline{p} \to W \to \ell\nu$ decays are shown in figure 2.

3. *Z* Decays into Electrons and Muons

In order to reconstruct $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$ events, both CDF and DØ select events with two reconstructed leptons. One leptons is required to pass 'tight' identification requirements, and the second lepton needs only to pass a looser set of requirements. The backgrounds to these events are less than 2%, coming mainly from QCD processes and cosmics. Table 2 gives the number of $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$ candidate events, $A \cdot \epsilon$ and luminosity used for each measurement. Results for the cross section times branching ratio of $p\overline{p} \to Z \to \ell^+\ell^-$ events are shown in figure 2.

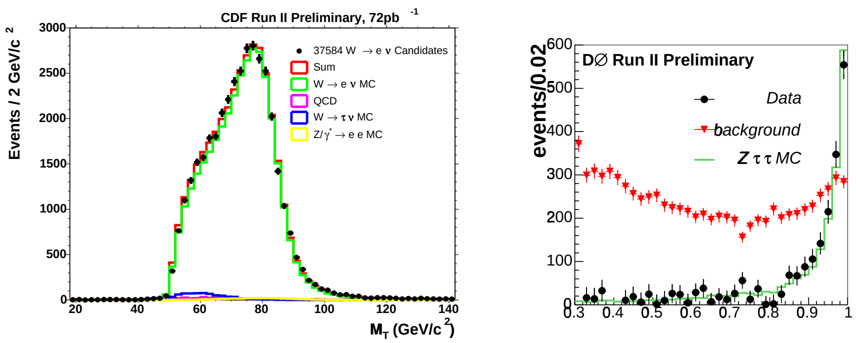

Fig. 1. Left: transverse mass for $W \to \mu\nu$ candidate events from CDF. Right: Output of a neural net for $Z \to \tau^+\tau^-$ events and backgrounds from DØ.

4. Tau-Lepton Reconstruction

Tau-leptons decay before they reach the detector and are therefore more difficult to reconstruct than electrons or muons. DØ uses a neural net (NN) to identify τ-lepton decays. The neural net uses electromagnetic energy and track momentum information and is trained using MC sample to find $\tau \to$ hadrons and $\tau \to e\nu_e\nu_\tau$ signals. Figure 1 shows the output of the neural net compared a simulation of the signal and the backgrounds. A cut is made on the output > 0.8 to select tau candidates. The NN is used to reconstruct $Z \to \tau^+\tau^-$ decays from a muon trigger sample; one of the taus is reconstructed using the NN, and the other by looking for $\tau \to \mu\nu_\mu\nu_\tau$ decays. 1946 $Z \to \tau^+\tau^-$ candidate events are found in 207 pb^{-1}. The background and acceptance times efficiency are estimated to be $(55 \pm 2)\%$ and $(1.65 \pm 0.09)\%$ respectively.

CDF has looked for τ-leptons using a more conventional method. To reconstruct tau decays into hadrons, CDF selects narrow, isolated jets with low track multiplicity. The invariant mass of the tracks and π^0s in the jet must be less than the τ-lepton mass. Using 72 pb^{-1} CDF reconstructs 50 $Z \to \tau^+\tau^-$ and 2345 $W \to \tau\nu$ candidate events with estimated backgrounds of $(21 \pm 6)\%$ and $(26 \pm 3)\%$ respectively. The acceptance times efficiency is about 0.5% for the $Z \to \tau^+\tau^-$ channel and $(0.91 \pm 0.05)\%$ for the $W \to \tau\nu$ channel.

The results for the cross sections times branching ratio are shown in figure 2.

5. Physics Results

The ratio R of the inclusive W and Z cross sections is defined as:

$$R = \frac{\sigma \cdot \mathrm{BR}(p\overline{p} \to W \to \ell\nu)}{\sigma \cdot \mathrm{BR}(p\overline{p} \to Z \to \ell^+\ell^-)} = \frac{\sigma(p\overline{p} \to W)}{\sigma(p\overline{p} \to Z)} \cdot \frac{\Gamma(Z)}{\Gamma(Z \to \ell\ell)} \cdot \frac{\Gamma(W \to \ell\nu)}{\Gamma(W)} \qquad (3)$$

Many uncertainties, including the largest uncertainty from the luminosity measurement, cancel in the ratio. Furthermore, R may be used to extract a value for the

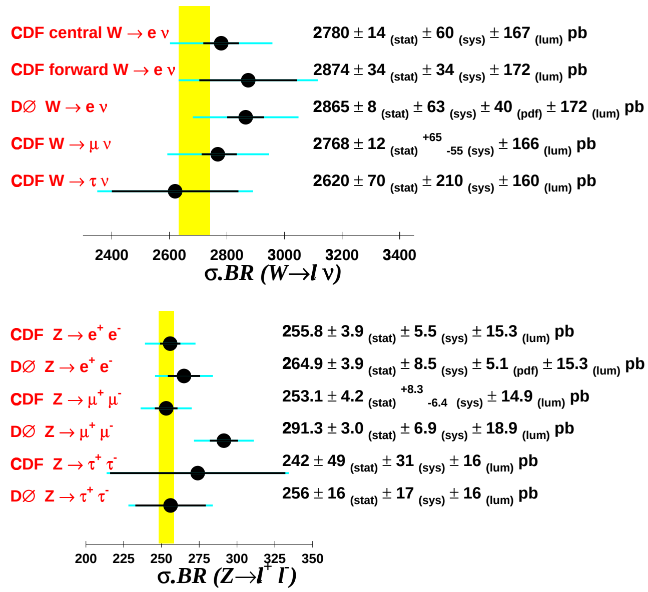

Fig. 2. Measured cross section time branching ratio for $p\overline{p} \to W$ and $p\overline{p} \to Z$ production at the Tevatron. The yellow band indicates the NNLO prediction.

width of the W-boson, $\Gamma(W)$. Using 72 pb^{-1} of data, CDF has measured:

$$R = 10.92 \pm 0.15(stat) \pm 0.14(sys) \tag{4}$$

Using Standard Model values for the ratio of the production cross sections and $\Gamma(W \to \ell\nu)$ [2,3], and the measured value of BR$(Z \to \ell\ell)$ [3], we obtain:

$$\Gamma(W) = 2079 \pm 41\ \mathrm{MeV/c^2} \tag{5}$$

which is as accurate as the 2004 world average value of $\Gamma(W) = 2124 \pm 41\ \mathrm{MeV/c^2}$ [3].

6. Conclusions

CDF and DØ have measured the cross section times branching ratio of W and Z bosons into all three lepton types, the first electroweak physics measurements from the Tevatron. These results may be used to measure many physics quantities in the Standard Model, including the width of the W-boson.

References

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